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The natural sectors of the inner Rottnest Shelf coast adjoining the Swan Coastal Plain

by D. J. Searle[1] and V. Semeniuk[2]
[1] 181 York Street, Subiaco, W.A. 6008.
[2] 21 Glenmere Road, Warwick, W.A. 6024.

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Abstract

The coastal environment of southwestern Australia encompassing the inner Rottnest Shelf that adjoins the Swan Coastal Plain, can be compartmentalised into five distinct natural sectors. Each sector has its own ancestral geomorphology, processes of sedimentation-erosion-transport, stratigraphic evolution and modern coastal geomorphology. The coastal sectors are: (1) Geographe Bay sector, characterised by a low hinterland and a broad, open, north-facing embayment and simple bathymetry, (2) Leschenault-Preston sector, characterised by a barrier dune-estuarine lagoons system and a simple submarine bathymetry, (3) Cape Bouvard-Trigg Island sector characterised by a complex bathymetry of marine ridge-and-depression morphology developed on Tamala Limestone, and extensive but discrete loci of Holocene sediment accumulation resulting in prograded beachridge and aeolian sand plains, (4) Whitfords-Lancelin sector, characterised by marine ridge-and-depression morphology, limestone rocky shores and isolated accretionary cusps of Holocene sediment, and (5) Wedge Island-Dongara sector characterised by a complex nearshore bathymetry of ridges-and-depressions, limestone rocky shores erosionally scalloped at a large scale, extensive shoreward migrating dune fields and asymmetric accretionary cusps of Holocene sediments.

The dominant stratigraphic units of the coast are: (1) Safety Bay Sand, (2) Becher Sand, (3) Leschenault Formation, (4) deltaic units, (5) Eaton Sand, (6) Cooloongup Sand, and (7) Tamala Limestone, and each of these units either directly influences the development of coastal morphology or is formed as a result of specific coastal environments. The main components of the coastal zone are Safety Bay Sand, Becher Sand and Tamala Limestone, and these have developed a varied range of nearshore, shoreline and onshore components.

The results suggest that the sector approach described herein is important to coastal studies of morphology, dynamics, history and function.

Introduction

The coastal environment of southwestern Australia presents an apparently simple system of rocky shores and sandy beaches. Yet within this system there is a marked compartmentalisation of coastal types, each with its own ancestral geomorphology, processes of sedimentation, erosion and transport, stratigraphic evolution and, as a result of the above, modern coastal geomorphology. This paper describes the results of several years work by the authors on the coast, culminating in the recognition that the modern coastline and inner portion of the Rottnest Shelf, inexorably linked in many ways, can be subdivided into distinct sectors. These sectors form the regional/subcontinental framework to understanding the coastal forms, coastal dynamics and coastal history that are evident at the large, medium and small scale.

The results of this paper have implications in studies on regional sediment transport pathways, coastal history, and coastal management. In coastal management, realistic comparisons can be made between genetically similar segments of coast within a given sector or, in some cases where dynamics/landforms are equivalent, between segments of different sectors. The delineation of natural sectors also allows for workers to determine the regional or local significance of particular tracts of coastline as well as the potential sediment dynamics of any particular location along the coast.

Methods

The results of this paper are based on fieldwork, reconnaissance surveys, aerial photograph studies, low altitude aerial surveys and literature review. Fieldwork involved study of geomorphology, sedimentology and stratigraphy by surface mapping, sample collection, coring/trenching and low altitude aerial flights. Sites where fieldwork was carried out include (Fig. 1): Geographe Bay, Leschenault Peninsula to Myalup area, Mandurah, Pt Becher to Trigg Island area, Whitfords to Two Rocks area, Lancelin, Jurien Bay, Green Head-Leeman, and Dongara area. Fieldwork was supplemented by reconnaissance surveys and low altitude aerial surveys to numerous other localities including the Cape Naturaliste area, Preston, Dawesville, Madora Bay, Guilderton, Cape Leschenault, Ledge Point, Wedge Island and Cervantes. Examination of aerial photographs, utilising black/white and water -penetrating colour photographs, was also undertaken.

The Rottnest Shelf and coast— Definition : this study

The Rottnest Shelf is defined to encompass the continental shelf between the Abrolhos Islands and Cape Leeuwin (Clarke 1926, Carrigy & Fairbridge 1954). However, this study concentrates only on the Rottnest Shelf adjoining the Swan Coastal Plain and excludes that portion adjoining the uplifted Leeuwin Block (Fig. 1). Specifically, the study area of this paper encompasses only the inner part of the Rottnest Shelf (i.e. landward of the 30 m isobath). This zone incorporates both the bathymetrically complex nearshore shelf with its islands, ridges, reefs, submarine sandy promontories, associated deep-water depressions (as exemplified by the Pt Becher-Garden Island area), and more simple inner continental shelf systems (such as offshore from Geographe Bay-Bunbury). Additionally, the study area encompasses the shoreline and the narrow near-coastal onshore area parallel to the coast. This latter coastal strip is included because landforms here either directly

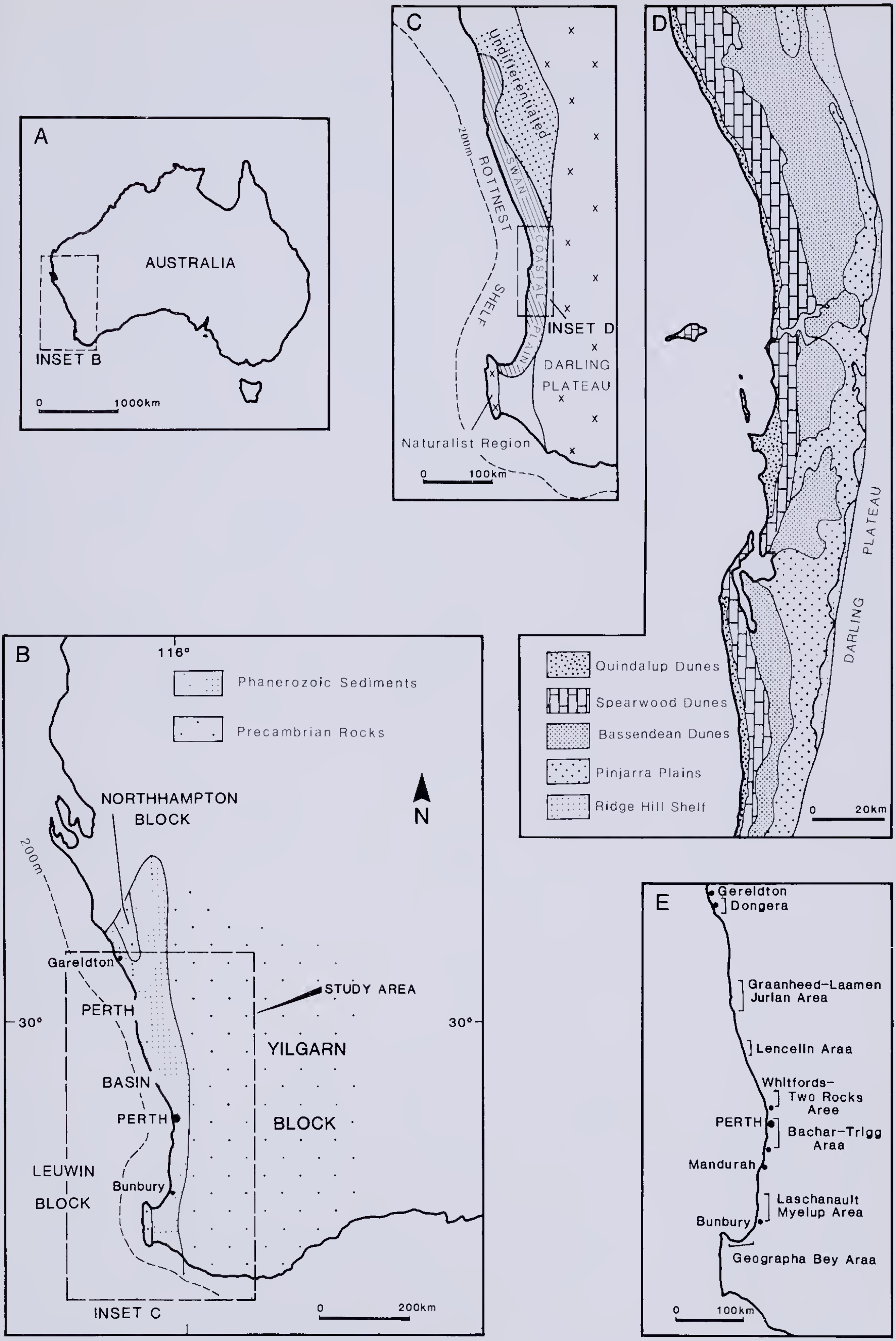

Figure 1.—Location diagrams and geomorphic/geologic setting.
A.—Location. B.—Geological setting of study area within Perth Basin. C.—Geomorphic setting of study area along shoreline of the Swan Coastal Plain. D.—Geomorphic units of central portion of Swan Coastal Plain (after McArthur and Bettenay, 1960). E.—Location of study sites.

influence the development of coastal form, or have developed as a result of Holocene coastal evolution, or are stratigraphically related to the modern coast. The northern limit of the study area is delineated at Dongara which forms a natural boundary to the Rottnest Shelf coast of this study. The southern boundary is the Leeuwin block which also forms a natural sharp boundary to the Rottnest Shelf coast of this study.

Previous studies/literature review

There are a number of papers written on the Quaternary geologic/geomorphic features of the Rottnest Shelf coast between Geographe Bay and Dongara. These are discussed below as: regional studies, coastal geomorphology, coastal stratigraphy, coastal processes.

The Rottnest Shelf coast was briefly described regionally by Jutson (1950), Davies (1977), Woods (1980) and Gill (1982). Jutson (1950) and Woods (1980) described the coastline as a single homogenous unit. Davies (1977) similarly treated large sections of the Rottnest Shelf coast as simple units and divided the coast into a "large barrier coast" between Geographe Bay and (approximately) Perth, and a "mainland beach coast" between Perth and Dongara. Gill (1982) classified the coast of this study into one type—the reef and aeolianite coast of Western Australia, which extends from Albany to Exmouth Gulf. All these classifications however are too broad and in many places inaccurate.

Studies in coastal geomorphology have been few in number (Fairbridge 1950, McArthur & Bettenay 1960, Semeniuk & Meagher 1981a, Woods & Searle 1983). Fairbridge (1950) described in some detail the geology and geomorphology of the Point Peron area; McArthur & Bettenay (1960) briefly described coastal dunes as part of their study of the Swan Coastal Plain, and Semeniuk & Meagher (1981 a, b) described the geomorphic processes and products of a barrier dune system in detail. Woods & Searle (1983) documented the prograded sedimentary plain of beach ridges/dunes at Rockingham and calibrated its age structure.

Studies in coastal stratigraphy are more numerous. Searle (1977) described the Quaternary stratigraphy of the Geographe Bay area. Semeniuk & Meagher (1981a,b) and Semeniuk (1983) described the stratigraphy and history of the Leschenault Inlet-Australind area. Searle & Logan (1979) reported briefly on the coastal stratigraphy near Mandurah. Passmore (1970), France (1978), Woods & Searle (1983), and Searle (1984) described the stratigraphy under prograded coasts in the Pt Becher, Rockingham, Cockburn Sound and Trigg Island area. Arakel (1980) described the physiographic setting, stratigraphy and sediments of a near-coastal lagoon at Leeman. Woods (1983) described the stratigraphy under the prograded plain at Jurien. On a more regional basis, Semeniuk & Johnson (1982) described the detailed stratigraphy under beach/dune coastlines, Semeniuk & Johnson (1985) outlined the stratigraphy of limestone rocky shores, and Semeniuk & Searle (1985 a) documented the gross stratigraphic settings of prograded coasts as a framework to studies on Holocene calcrete.

Numerous scattered works dealing with coastal processes also have been published. In addition to those papers cited above which in part also may describe coastal processes of sedimentation, erosion and transport, there are the works of Kempin (1953), Silvester (1957, 1959, 1961, 1963, 1974) Welch (1964), Ruck (1974), Searle & Logan (1978, 1979), Eliot *et al.* (1982), Clarke & Eliot (1983) and Semeniuk & Searle (1985 c). These authors described seasonal or long term fluctuations along sand shorelines or develop models for sediment transport. Studies in coastal oceanography in this region of the Rottnest Shelf include those by Silvester (1957, 1963, 1974), Easton (1970), Department of Construction (1977), Paul & Seale (1978) and Steedman & Craig (1979, 1983). However, there is also a large amount of unpublished data in numerous reports commissioned by and submitted to government agencies, local shires and private organisations.

It is evident from this literature review that no works to date have adequately described or classified the full length of the coastline of the Rottnest Shelf to the detail presented here. Rather, individual studies have concentrated on the details of local areas. Where authors have attempted more regional/subcontinental classifications, the results are either inaccurate or too broad.

Regional geological/geomorphic setting

The coastal lowlands of southwestern Australia comprised of Holocene sediments and/or Pleistocene materials is the seaward portion of the Swan Coastal Plain (McArthur & Bettenay 1960). This plain is composed of Quaternary sedimentary materials which are part of the Phanerozoic Perth Basin (Playford *et al.* 1976). The Swan Coastal Plain is comprised of several geomorphic systems which, from east to west, are (Fig. 1):

- Ridge Hill Shelf—a unit of Pleistocene laterite and sand
- Pinjarra Plain—a unit of Pleistocene to recent alluvial landforms and sediments
- Bassendean Dunes—a unit of degraded Pleistocene aeolian landforms and quartz sand
- Spearwood Dunes—a unit of Pleistocene limestone ridges with intervening swales (= depressions)
- Quindalup Dunes—a unit of Holocene dunes and beaches forming along the modern coast.

To the north of the study area additional units make appearances, e.g. Eneabba Plain (Lowry 1974, Playford *et al.* 1976).

The Spearwood Dunes and Quindalup Dunes are the dominant landforms along the modern coastline of southwestern Australia and most coastal features are a direct result of the disposition and interrelationships of these units. For instance, limestone rocky shores result where the Spearwood system occurs at the coast, and nearshore island systems such as the Garden Island-Carnac Island chain result where ridges of Spearwood Dunes were incompletely inundated by the last postglacial transgression. The occurrence/disposition of Spearwood Dune ridges also has a direct influence on the development of local Holocene sediment buildups (= the Quindalup Dunes).

Table 1

Description of coastal Quaternary formations, Swan Coastal Plain

	Description	Stratigraphic relationships	Age	Coastal landforms	Occurence	Author(s)
Safety Bay Sand	buff to cream laminated and cross-laminated sand and shelly sand; soil horizons	onlaps Tamala Limestone and overlies Becher Sand or Leschenault Formation	Holocene	beaches, beachridges and various types of dunes	throughout study area	Passmore (1970)
Becher Sand	grey bioturbated to structureless sand and shelly sand with seagrass biota assemblage	overlies Tamala Limestone or Cooloongup Sand; overlain by Safety Bay Sand	Holocene	seagrass banks and submarine sandy promontories	mainly developed in Cape Bouvard-Trigg Is. sector and Geographe Bay sector; patchy development elsewhere	Semeniuk & Searle (1985b)
Leschenault Formation	bioturbated and interlayered grey sand, muddy sand and mud with estuarine biota	overlies Eaton Sand; overlain by or interfingers with Safety Bay Sand	Holocene	estuarine lagoons	mainly developed in Leschenault Preston sector and locally in Geographe Bay sector	Semeniuk (1983)
Deltaic units	complexly interlayered and interdispersed sand, muddy sand and mud, locally shelly	overlies Tamala Limestone, Eaton Sand, Cooloongup Sand or even older units; interfingers with estuarine deposits	Holocene	deltaic landforms	mainly developed in Leschenault-Preston sector	not defined
Eaton Sand	yellow-orange quartzose sand (locally with shell layers and limestone)	overlies Tamala Limestone; overlain by Leschenault Formation	Pleistocene	linear, shore-parallel ridges and elevated sand plains	developed in Leschenault-Preston sector	Semeniuk (1983)
Cooloongup Sand	yellow-orange quartzose sand	overlies Tamala Limestone; overlain by Becher Sand	Pleistocene	mainly subsurface	developed in Cape Bouvard-Trigg and Whitford-Lancelin sectors	Passmore (1970)
Tamala Limestone	quartzo-calcareous sand variably cemented into limestone, friable limestone and calcrete capstone	unconformably overlain by combinations of all younger formations, depending on location	Pleistocene	linear, shore-parallel onshore ridge and wetland system, and nearshore/offshore submarine ridge-and-depression systems	throughout the study area	Logan *et al.* (1970) Playford & Low (1972)

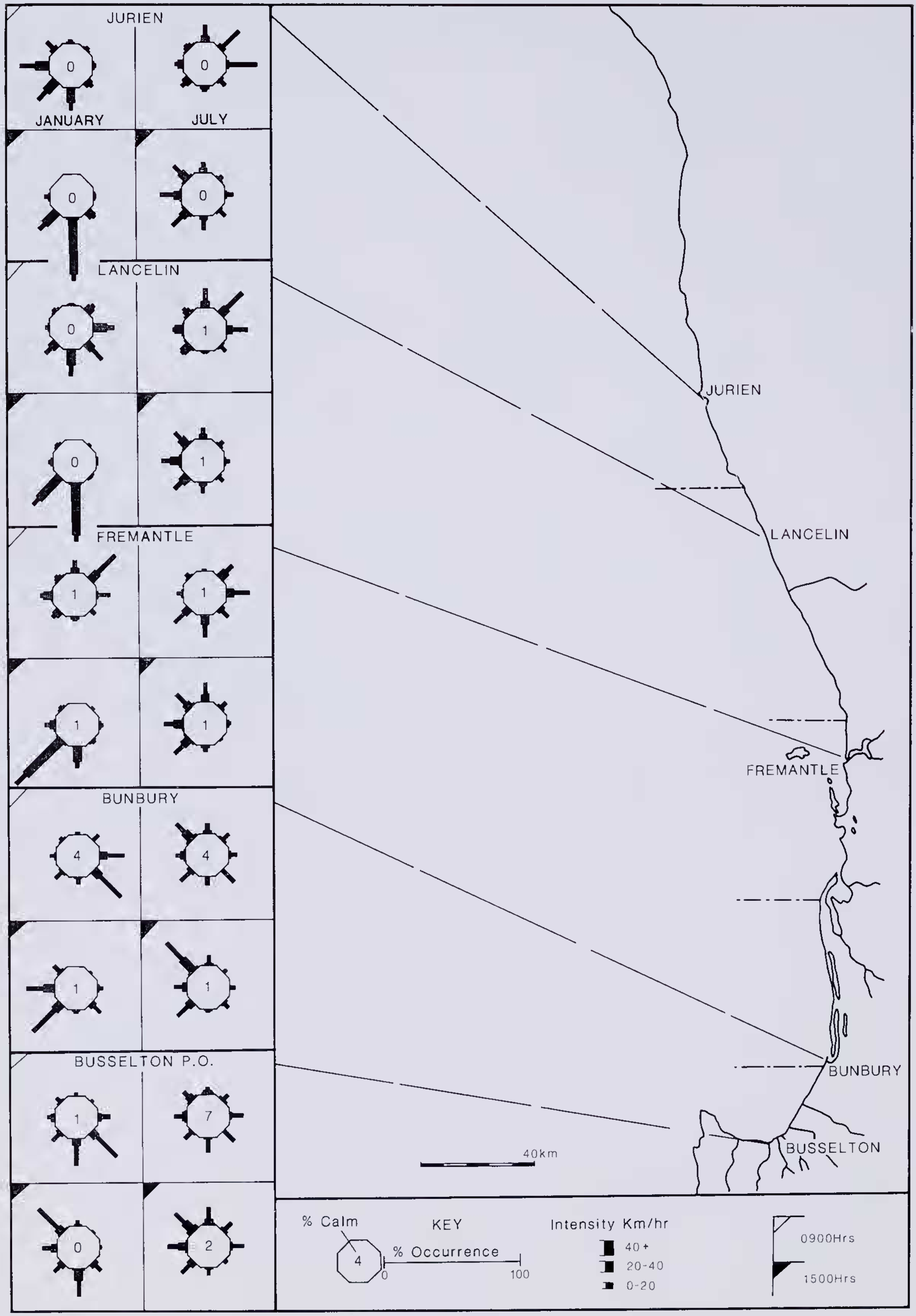

Figure 2.—Wind rose diagrams for selected localities along the southwestern coast. Each locality is typical of a given coastal sector.

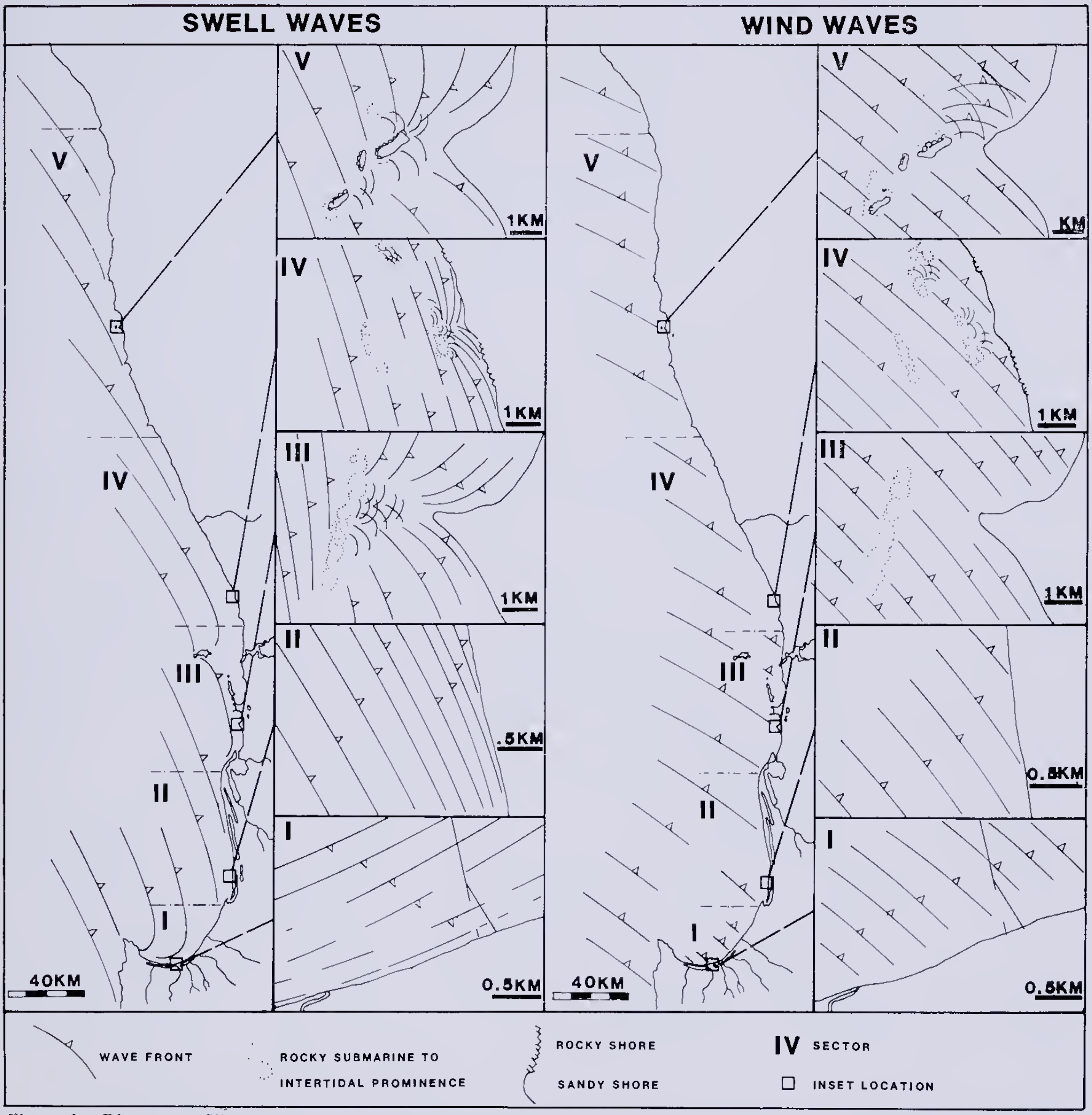

Figure 3.—Diagram to illustrate the pattern of swell waves and wind waves along the southwestern coast of the study area. The overall regional swell and wind wave pattern is shown on the left; the variability of wave pattern developed as the waves interact with the various coastal bathymetric types is shown on the right. The diagram is intended to convey the variability and modification of waves that may ensue in the near coastal zone. Wave fronts have been traced off aerial photographs.

Geologically the Spearwood Dunes is referred to the Tamala Limestone which is a ribbon-to wedge-shaped limestone unit that parallels the coast in outcrop on the subaerial parts of the Swan Coastal Plain. It crops out along the shoreline (where not covered by Quindalup Dunes), it comprises the core of nearshore and offshore islands, and submarine ridges, and it dominantly underlies the vast Continental Shelf (Collins, 1983; Searle, 1984). The limestone has been described by various authors including Teichert (1947), Fairbridge (1950), Seddon (1972), Playford *et al.* (1976), Playford & Leech (1977), Semeniuk (1983) and Semeniuk & Johnson (1985).

The coastal dune and beach sediments of the Quindalup Dunes stratigraphically are termed the Safety Bay Sand (Playford *et al.* 1976). This formation extends discontinuously along the coast and is best developed in embayments, sheltered bays and tombolo settings where it forms prograded sediment bodies within which there is a distinct stratigraphic sequence of beach sand overlain by dune sand (Searle 1977, 1984; Semeniuk & Johnson 1982; Semeniuk 1983; Woods & Searle 1983)

The sediments of submarine seagrass banks and sandy promontories have recently been assigned formation status and are referred to the Becher Sand (Semeniuk & Searle 1985b). This unit forms under seagrass cover and is composed of structureless to bioturbated quartz and skeletal sand, muddy sand and mud. The unit generally underlies prograded plain systems beneath a cap of Safety Bay Sand beach/dune sequences (Searle 1984).

Stratigraphic Framework

There is a recurring pattern in distribution of the main Quaternary formations throughout the entire study area. The main formations that directly develop coastal morphology and hence are relevant to this paper are: (1) Safety Bay Sand, (2) Becher Sand, (3) Leschenault Formation, (4) deltaic units, (5) Eaton sand, (6) Cooloongup Sand, and (7) Tamala Limestone. These abut or overlie older Quaternary units such as Bassendean Sand or Australind Formation, or may overlie pre-Quaternary materials. Quaternary units relevant to this paper are described in Table 1. The stratigraphy for individual sectors is described later in the relevant sections.

Dynamics of the coast : meteorology/Oceanography

Meteorology

The significant meteorological factor for coastal areas is wind: it generates wind waves and mobilises aeolian sand. The coastal area of the inner Rottnest Shelf spans a climatic range from subtropical humid at Geographe Bay to subtropical arid at Dongara and, as may be expected, there is gradual change in features of the wind system although regionally there is an overall consistency in the wind pattern. For instance, there is a clear division over the entire study area between summer and winter patterns which are related to the position of eastward-travelling high/low pressure systems (Gentilli 1972).

Winter is characterised by storms with intervening calm weather. Storms typically have mean wind speeds of up to 20 m/s for 6-24 hours duration, and prevail from northwest, west and southwest. Two to four (to ten) such storms may be expected each winter with minor storms occurring every two weeks (Steedman & Craig 1979). During summer, seabreeze/landbreeze systems control the winds in the coastal area. Seabreezes blow from west to southwest in southern areas and from southwest to south in northern areas. Speeds are up to 15 m/s in southern areas and *ca* 20 m/s in northern areas. Seabreezes are significant, firstly in that they induce littoral drift along the shore and, secondly they mobilise sand in aeolin drifts onshore. The direction and abundance of dune blowouts reflect the direction and intensity of seabreezes. Landbreezes have no significant part in coastal processes except in two situations: (1) eastward side of islands, and (2) Geographe Bay area.

In summer there is also the possibility of extra-tropical cyclones travelling through the study area. Although weakening, these are still capable of producing extreme wind and waves. Fig. 2 summarises the formation on wind essential to this coastal study area.

Oceanography

The Rottnest Shelf is exposed to the regional wave climate and circulation patterns of the southern Indian Ocean (Department of Construction 1977; Steedman & Craig 1979, 1980, 1983; Steedman & Associates 1981). Coastal areas of the shelf are subject to these regional processes as well as locally-generated wind waves and currents. Tidal ranges in coastal areas of this shelf are small (Hodgkin & DiLollo 1958, Easton 1970), and are not significant in sedimentary processes except in constricted channels/passages.

Wave Climate: Oceanic swells with periods mainly from between 10 and 14 seconds, and deriving from between west and southwest dominate the regional wave climate and impinge year round on the entire Rottnest Shelf coast (Silvester 1963, Commonwealth Depart of Construction 1977). As swell passes over the shelf it is refracted from deepwater paths by 5 to 15° on the outer shelf and by about 5° or less on the lower gradient inner shelf (Collins 1983). The complex bathymetry of the nearshore dampens, refracts and diffracts both swell and locally-generated seas, creating complex convergences and divergences of wave orthogonals (Fig. 3). Swell is also markedly refracted around Cape Naturaliste (Fig. 3).

Locally-generated wind waves also are a significant influence, supplementary to swell, close inshore and during storm events. Wind waves commonly have a period less than 10sec and are generated under the prevailing wind system associated with the easterly-moving pressure cells (Gentilli 1972), and by the summer landbreeze/seabreeze system. Winter storms generate locally significant seas, with 8 to 10 second periods, which approach first from the northwest, then west, before shifting to southwest as the storm passes over the coast.

In summary therefore, depending on the extent that offshore island/ridge barriers are developed, the incident waves approaching the coast may be: (1) swell waves, (2) wind waves, (3) wind waves *and* swell, or (4) wind waves *with dampened swell.*

Circulation: The regional circulation pattern as described by Andrews (1977), Kitani (1977), Cresswell *et al.* (1978), Golding & Symmonds (1978) for areas of the continental shelf and shelf edge have little influence on nearshore waters, particularly shoreward of the 20 m isobath. Nearshore circulation on the Rottnest Shelf is largely wind driven with regional oceanic circulation exerting only a minor residual effect (Steedman & Craig 1979, 1980; Steedman & Associates 1981). In restricted nearshore environments like Cockburn Sound, wind forcing results in current gyres, with only limited exchange with adjacent shelf waters. Outside these embayments, winds tend to generate transient north-south flows typically in the range of 5 to 20 cm/sec (Steedman & Associates 1981). Summer wind patterns tend to generate northward flows, winter winds generate a southward flow. In addition, regional oceanic circulation involves current drifts of about 5 cm/sec, also directed north in summer, and south in winter.

Geomorphic components of the coast at the large scale to small scale

Localized Holocene sediment accretion together with erosion of the partially-inundated Pleistocene aeolinite topography has developed a complex array

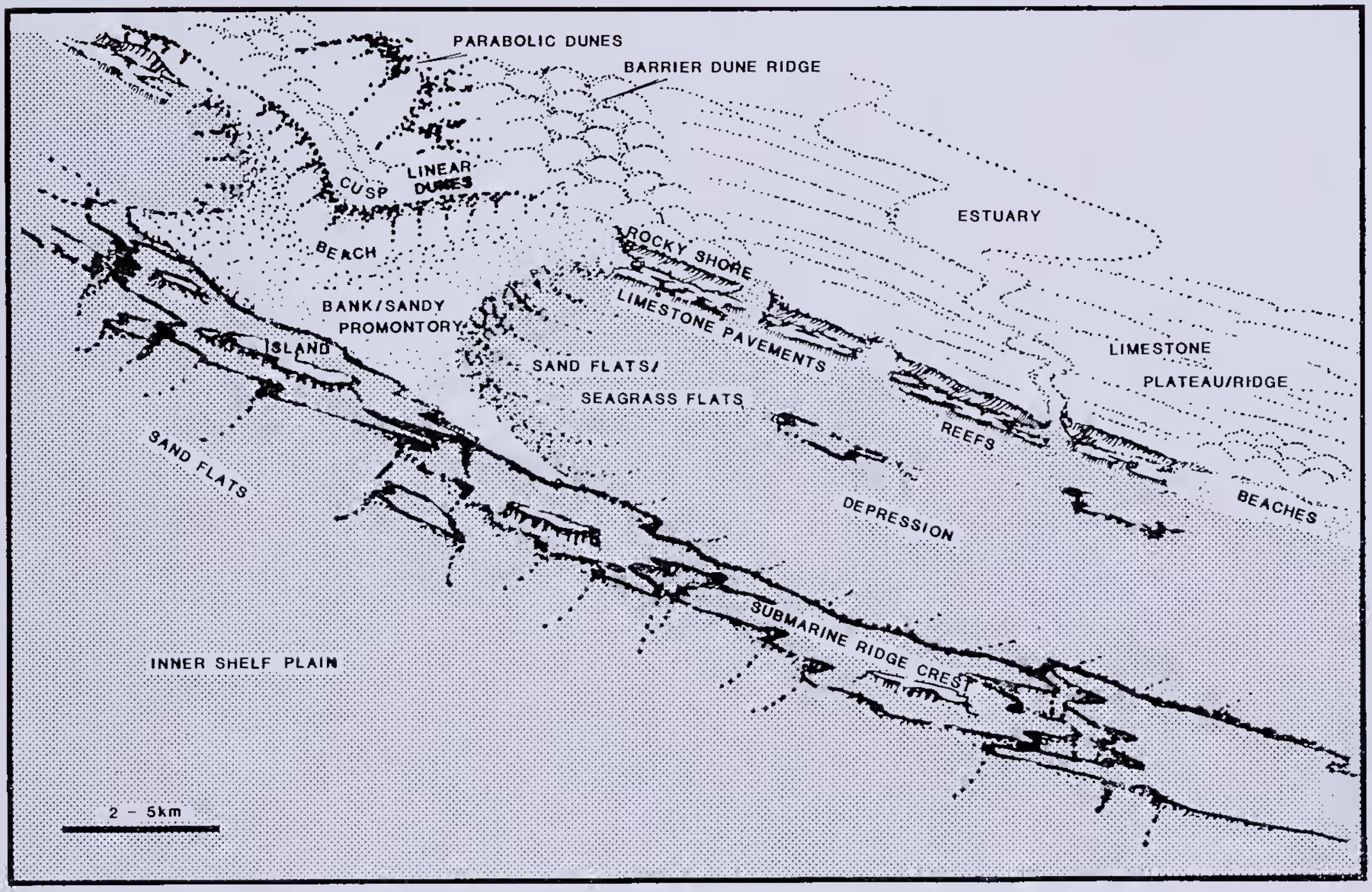

Figure 4.—Schematic diagram illustrating typical components of the coastal zone in southwestern Australia.

of coastal components along the southwestern coast of Australia. The main components of this coastal region evident at the large, medium and small scale, listed within a framework of nearshore-shoreline-onshore units, are as follows (Fig. 4):

Nearshore components
- islands
- submarine ridges and reefs
- depressions
- sand flats and seagrass flats
- limestone pavements
- sand promontories/banks

Shoreline components
- rocky shores
- beaches

Onshore components
- beach ridges and linear dunes
- parabolic dunes (blowouts)
- barrier dune ridges
- limestone plateau /ridges
- lagoons/estuaries/wetlands

Nearshore Components: Islands, submarine ridges and reefs represent various intergradational stages of development and/or breakdown of ridges of Tamala

Limestone inundated by the present sea. Deeper-water depressions in the nearshore environment are inundated inter-ridge swales. Limestone pavements are planed submarine extensions of limestone rocky shores and the nearshore islands, ridges and reefs. Sand flats and seagrass flats are seaward extensions of sandy shorelines or are sand covered submarine plains. Sand promotories/banks are mound-like submarine sediment bodies vegetated by seagrass that have developed in the inundated inter-ridge depressions during the Holocene; where nearly emergent, the banks can be topped by extensive beach ridge and dune plains that later extend out from the mainland as broad cuspate promotories.

Shoreline Components: Shoreline components are rocky shores and beaches. The abundance of these shore types varies according to location: rocky shores are more common north of Perth; sand shores are the more common type south of Perth. The rocky shore environment is complex and varied, with erosional products of cliffs, breccia wedges, shore platforms and breccia pavements predominating (Fairbridge 1950, Semeniuk & Johnson 1985); however there is also local sand accumulation on these shores in pocket beaches and as sheets. Beaches in this region can be subdivided on normal global criteria into shoreface, foreshore, backshore and beachridge/dune environments (Semeniuk & Johnson 1982).

Onshore Components: The narrow subaerial coastal strip parallel to the shoreline is comprised of varied landforms, depending on location. Mostly it is shore-parallel Tamala Limestone ridges. In some localities these ridges separate a lagoon from the Indian Ocean (e.g. Lake Clifton). In other localities a barrier dune of Safety Bay Sand separates an estuary and lagoon (e.g. Leschenault Inlet and Lake Preston) from the Indian Ocean. Locally in the protected lagoons where there is fluviatile drainage there are small deltas such as Collie River delta and Harvey River delta. On sediment-accreting (or prograded) coasts, the onshore is composed of

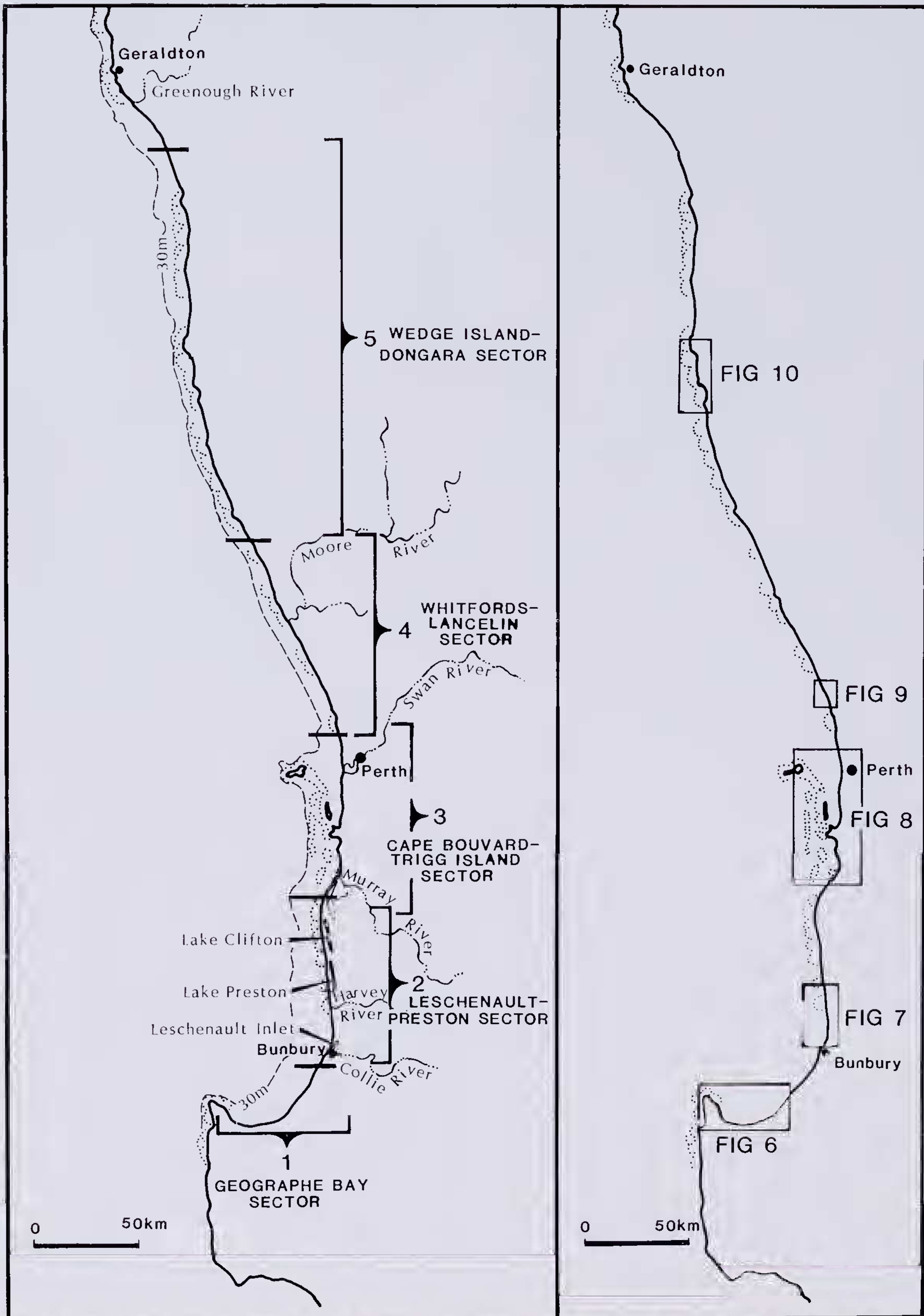

Figure 5.—A.—Map showing the location of the five coastal sectors along the shoreline adjacent to the Swan Coastal Plain in southwestern Australia. B.—Locations of detailed maps shown in Figures 6-10.

beachridges and dunes. Dunes may also comprise the dominant onshore landform along a rocky shoreline where aeolian sand has encroached upon and buried a limestone plateau/ridge hinterland. Dune landforms vary from shore-parallel ridge types to parabolic dune (blowout) types. Dune landforms may form barrier ridge systems, or tombolos or (triangular) cusp systems.

The natural sectors of the Rottnest Shelf coast

The coast of the Rottnest Shelf adjoining the Swan Coastal Plain may be divided into five sectors, each distinguished by a unique combination of modern onshore and offshore geomorphology, coastal processes and Holocene sediment accumulations. The sectors from south to north are: (1) Geographe Bay Sector, (2) Leschenault-Preston Sector, (3) Cape Bouvard-Trigg Island Sector, (4) Whitfords-Lancelin Sector, and (5) Wedge Island-Dongara Sector.

Each of these sectors are described below in terms of (1) bathymetry (= offshore geomorphology) and onshore geomorphology, (2) stratigraphic framework, (3) sedimentation and erosion, and (4) resultant coastal morphology. A summary of the salient features of these sectors is presented in Table 2 and Figs 5 and 6-10.

Geographe Bay Sector

Geographe Bay is a broad, 100 km wide, north-facing embayment at the southern end of the Rottnest Shelf. The western headland is well defined by an upthrust fault block of Precambrian rock. The eastern margin is not well defined and the arcuate shoreline curves into north-south alignment of the main Rottnest Shelf coast at about Casuarina Point. This sector is characterised by a simple offshore bathymetry, a lowland onshore, and Holocene sedimentation confined to an onshore beachridge/strandplain to nearshore sand sheet deposits.

Bathymetry and Onshore Geomorphology (Fig. 6): The coastal hinterland and seafloor of Geographe Bay slope gently northward to depths of 12 to 15 m where the embayment floor opens out onto the inner Rottnest Shelf. Onshore, undulating hummocks and low discontinuous ridges 1 to 2 m high are shore-parallel bands of Quaternary (Pleistocene-Recent) coastal deposits that generally young towards the present shore. A narrow band (average 500 m wide) of Holocene beachridges is developed behind the contemporary beach shoreline. In swales and inter-beachridge areas there are numerous narrow lagoons and impounded drainage channels. Offshore the gently sloping floor of the bay is a sand sheet, vegetated by dense seagrass meadows. The sand sheet extends from near the beach to about 12 m depth about 4 km offshore. Below this depth the sand sheet thins to expose underlying Pleistocene limestone that locally forms discontinuous 1 to 3 m high shore-parallel ridges. Because of their lack of expression and continuity, submarine limestone ridges have only minimal influence on sedimentation.

An array of sand floored scours aligned transverse to the shore are developed in the meadow cover of the offshore sand sheet. Up to 250 m wide, and incised up to 1.5 m into the sand, the scours extend from near the beach to the thinning northern edge of the sand sheet offshore. Their orientation reflects the orthogonals of the refracted and prevailing westerly swell in the embayment. Towards their landward extremities the scours merge with elongate sand bars

Table 2

Summary of main feature of the coastal sectors

Sector	Description			
	Nearshore bathymetry	Coastal form	Landforms developed by Holocene accretion	Onshore hinterland
Geographe Bay	simple—gently-inclined shelf	even, arcuate low coastal plain	narrow shore-parallel beachridge/dune belt	low surface of limestone and alluvial plain
Leschenault-Preston	simple—gently-inclined shelf	even, linear shore-parallel barrier systems with intervening estuaries and lagoons	linear barrier dune system and protected estuarine deposits	linear ridges of Pleistocene limestone and sand
Cape Bouvard-Trigg Is.	complex—composed of islands, submarine ridges, reefs and intervening depressions	cuspate to tombolo coast forming broad accretionary plains prograded from a limestone hinterland	merged cusps and tombolos developing a broad sand plain	linear ridges of Pleistocene limestone
Whitfords-Lancelin	complex—composed of submarine ridges, reefs and intervening depressions	dominantly straight rocky shore with isolated accretionary cusps	isolated cusps and landward migrating dunes	linear ridges and low plateau of Pleistocene limestone
Wedge Is.-Dongara	complex—composed of submarine ridges, reefs and intervening depressions	dominantly scalloped rocky shore with isolated accretionary cusps and landward migrating dune fields	landward migrating dunes and isolated cusps	linear ridges and low plateau of Pleistocene limestone

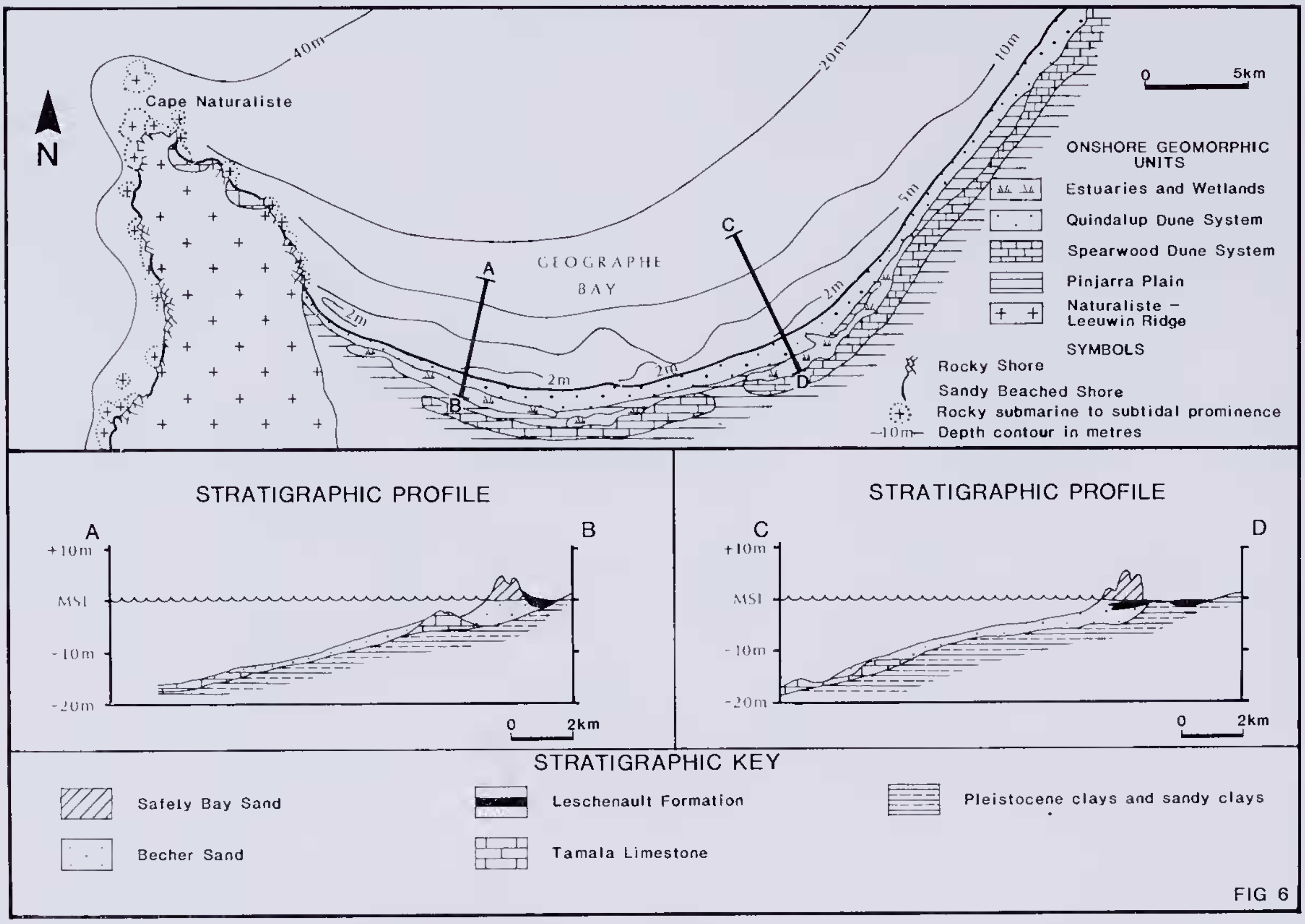

Figure 6.—Portion of coast of the Geographe Bay Sector showing: arcuate Holocene dune system, general coastal form, geomorphic units, simple nearshore bathymetry, and selected stratigraphic profiles.

(up to 3 m relief) oriented at a lesser angle to the shore. The interaction between the shoaling swell, the extensive meadow cover, sand floored scours and bars influences the distribution of wave energy along the coast, and produces a low amplitude sinuosity in coastal alignment. The formation, morphology, and long term dynamics of the scours and bars are discussed by Searle (1977), Paul & Searle (1978) and Searle & Logan (1978).

Stratigraphic Framework (Fig. 6): Holocene sediments form a seaward thinning wedge and reach up to 8 m thick locally beneath the larger beachridges in this area. Offshore Holocene sediments decrease in thickness to an average thickness of about 1.5 m and further offshore become thin and discontinuous, exposing a gently north-sloping unconformity cut mainly on Tamala Limestone, and an underlying semi-lithified green sandy clay. The limestones are aeolian and marine, and form a thin (less than 5 m thick) discontinuous capping on the underlying clay. In the far western part of Geographe Bay adjacent to the Dunsborough Fault and the Leeuwin-Naturaliste Block headland, Holocene sediments also overlie biotite-rich green sands (of indeterminate age) and Precambrian rocks.

The onshore Holocene sediments are mainly Safety Bay Sand, (beach and beachridge sediments), consisting of quartzo-feldspathic, skeletal sand. Lenses and ribbons of estuarine mud (stratigraphically correlated with the Leschenault Formation of Semeniuk, 1983) have been incorporated in the Holocene sequence due to the impounding of the natural drainage system behind and within the beachridges. The offshore sand sheet is referred to the Becher Sand.

Sedimentation/erosion: In the long term (past 5 000 years) sediment accretion in Geographe Bay has resulted in an average progradation of about 500 m and the development of a thin but extensive sand sheet offshore. Although there has been net accretion, aerial photographs indicate at some time earlier in the Holocene there also were pronounced periods of coastal erosion. Quartzo-feldspathic sands have been reworked from older Pleistocene coastal deposits, probably during the post-glacial marine transgression. The skeletal sediment component has been generated mainly within the embayment by the carbonate-producing organisms of extensive seagrass meadows and, to a lesser extent, by organisms inhabiting adjacent bare sand. Both the rate and extent of sediment accretion have been limited by the lack of a significant post-transgression source of quartzo-feldspathic sand and losses of skeletal sediment from the embayment in the littoral transport system.

In the short term, sedimentation is controlled by the interaction of: (1) the prevailing refracted and shoaling swell regime, (2) locally-generated wind waves, (3) wind-driven nearshore circulation, (4) the extensive seagrass meadow-covered shoreface, (5) the scour/bar systems, and (6) the arcuate north-facing geometry of the embayment. Under prevailing conditions, refracted westerly swell and longer period

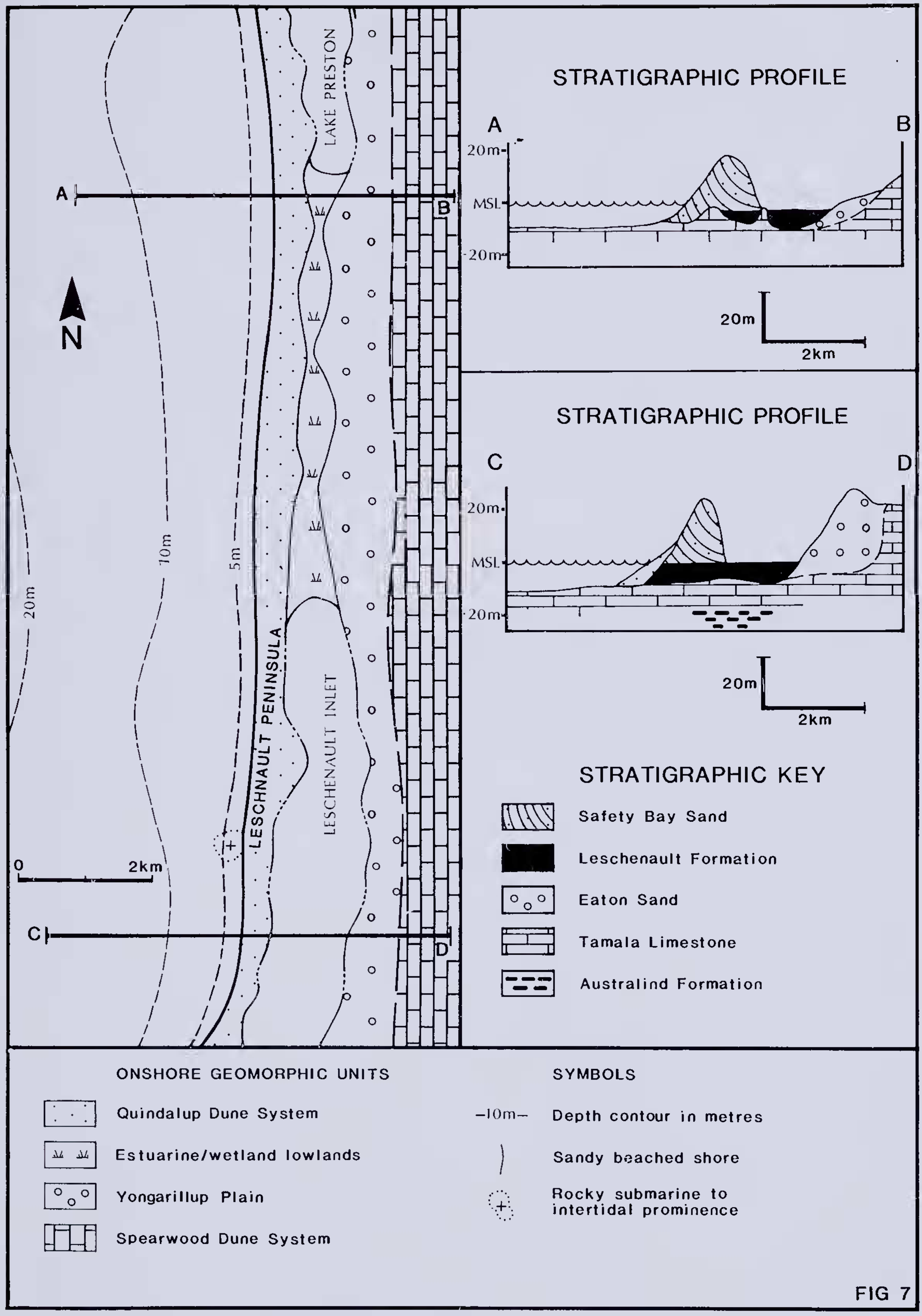

Figure 7.—Portion of coast of the Leschenault-Preston Sector showing: the linear Holocene barrier dune, general coastal form, geomorphic units, simple nearshore bathymetry and selected stratigraphic profiles.

wind waves impinge on almost all the Geographe Bay shoreline. Sediment tends to be transported shoreward from the scours and bars toward the shore. Wave induced and westerly wind generated currents then impel a littoral movement eastward.

In winter months (and rarely in the summer due to cyclones) storm conditions disrupt the prevailing system. Northerly storm waves impinge on the whole shoreline. In the eastern part of the embayment particularly, the storm waves and winds impel a westerly littoral transport. Locally the littoral currents move offshore along the scour/bar systems entraining some of the littoral drift. The sediment supplied in this manner to the scour/bar system is then returned gradually to the shore and nearshore by prevailing conditions. Easterly (landbreeze) winds also generate analogous westward littoral transport and seaward diversions to the scour/bar systems. Diversion of artificial drain mouths and natural river mouths clearly indicates net littoral transport is eastward within the embayment.

Resultant Coastal Morphology: The coastal form of Geographe Bay is largely developed by the configuration of Pleistocene limestone. Holocene sedimentation in Geographe Bay has not substantially altered the ancestral coastal morphology. During the transgression, the low ridges of Pleistocene limestone were probably subject to erosion, resulting in the stratigraphic discontinuity observed at present. Limited sediment accretion along the shore has resulted in a seaward migration of the shoreface along a broad front, grossly maintaining the arcuated bay form and developing a beachridge ribbon peripheral to the bay. The development of successive beach ridges during the coastal progradation also has significantly impeded the natural drainage from the hinterland, resulting in the elongate fresh to brackish lagoons/inlets developed in and behind the ridges.

Leschenault-Preston Sector

The Leschenault-Preston sector of the Rottnest Shelf coast extends about 80 km in a northerly alignment. The southern margin is defined by Casuarina Point, the northern margin is defined by Cape Bouvard. This sector is characterised by a simple offshore bathymetry, a series of parallel dune systems onshore and Holocene sedimentation largely confined to a barrier dune system with its accompanying lagoons.

Bathymetry and Onshore Geomorphology (Fig. 7): The onshore area in this sector is dominated by a series of Spearwood and Quindalup dune ridges which form a 45 to 60 m high and 4-6 km wide topographic barrier between the main low-lying Swan Coastal Plain and the inner Rottnest Shelf. The ridges trend either parallel or slightly oblique to the coast. The Quindalup Dunes occur at the present coast where they form a separate ridge as a barrier dune system, or flank the seaward face of a larger Spearwood dune ridge. Older, less prominent dune systems form an undulating lower coastal hinterland.

In depressions between major dune ridges there are elongate, shallow (usually less than 2 m deep) water bodies. Harvey estuary, Peel Inlet and Lake Clifton occur in depressions between Spearwood Ridges. Lake Preston and Leschenault Inlet occur between a Quindalup ridge and a Spearwood ridge; Leschenault Peninsula and the Preston Barrier, both of which are barrier dune systems, separate the lagoons/inlets from the ocean. The main drainage in this sector is either into Leschenault Inlet or Harvey estuary.

The bathymetry of this coastal sector is simple. A coast of beach/beachridge/dune is developed on the seaward flank of the Quindalup barrier dune or a Spearwood ridge. Seaward of the shore, the sand-mantled shoreface slopes seaward to merge with the inner shelf plain about 1-2 km offshore in water depths of 12 to 15 m. Low-lying limestone pavement surfaces and discontinuous limestone ridges (1-2 m high) and relict beach-rock slabs (Semeniuk & Searle, 1985c) are exposed on the inner shelf plain, and protrude through a sand veneer in several locations. These rocky areas are not sufficiently prominent or continuous to influence sedimentation in this sector.

Stratigraphic Framework (Fig. 7): This sector contains a complicated array of stratigraphic units which include Pleistocene units: Tamala Limestone, Eaton Sand and Australind Formation; and two Holocene units: Safety Bay Sand and Leschenault Formation. The Australind Formation is a calcareous estuarine unit; the Tamala Limestone is aeolian and marine sediment; and the Eaton Sand is a shoestring-shaped body of coastal sand which is thickest along the eastern shore of Leschenault Inlet and thins rapidly westward. The Pleistocene units occur in stratigraphic superposition.

Quartzose and calcareous sand of the Safety Bay Sand dominate the shoreline throughout this sector. These sands form the barrier dune system of the Leschenault Peninsula and Preston Barrier, mantle the seaward face of Spearwood ridges, and extend over the shoreface down to depths of 12 to 15 m. Maximum thickness of the Safety Bay Sand is up to 40 m in the Leschenault Peninsula. To the north the Holocene sands may overlie semi-lithified dune sands and limestone of the Tamala Limestone. In the Leschenault Peninsula area and northwards, Safety Bay Sand also overlie and locally interfinger with Holocene estuarine mud and sand (= Leschenault Formation). The Safety Bay Sand passes offshore into sand sheets that variably overlie areas of Leschenault Formation, the Eaton Sand, or the Tamala Limestone.

The Leschenault Formation, up to 6 m thick, extends as a ribbon from the floor of the contemporary estuarine lagoon to underneath the Safety Bay Sand of the barrier dunes. This mud/sand sheet largely overlies the Eaton Sand, but may also directly overlie an irregular Tamala Limestone surface.

Sedimentation/erosion: Throughout the Holocene the west-facing shores of this sector have been fully exposed to the wind, wave and current regime of the Rottnest Shelf. As a result, there has been a continuing reworking of the Holocene sediment bodies developed initially during the late stages of the post-glacial transgression. In response to the prevailing onshore nature of the energy regime, erosion of the seaward face of this sandy coast is accompanied by dune migration eastward across the barrier dune system, and up the seaward flank of the Spearwood Dunes of the shoreline to the north. There is also significant longshore transport of material in the littoral and nearshore zones. Under conditions of combined prevailing wind waves and swell, sediment is impelled northward along the upper shoreface. This pattern is interrupted by northerly storms which impel a reverse transport. However, although dramatic, these interruptions are only interim and net transport year round is northward.

The sediment available to this coast during the Holocene mostly has been quartz sand (except in the sheltered lagoonal environments where calcareous mud and terrigenous mud have accumulated). The source of this sand largely has been the reworking of pre-Holocene materials in the adjacent shelf and coast during the latter stages of the post-glacial transgression. River-transported sand supplements this source only to a very minor degree. Supply of sediment from Geographe Bay to the south has been minimal as indicated by provenance studies (Searle and Semeniuk, in prep.).

Resultant Coastal Morphology: The exposure and continuing reworking of the coastal deposits of this sector throughout the Holocene has produced major changes in the coastal morphology. Some time after the transgression a major shore-parallel, emergent barrier dune system developed several kilometres seaward of the present Leschenault Peninsula. At its southern end the barrier may have joined with Casuarina Point. At its northern end, the barrier may have developed from a shoreline founded on Spearwood Dune ridges located some distance to seaward of the present shore (probably about 3 km). The sheltered waters to landward became an elongate lagoon system, the combined Lake Preston and Leschenault Inlet. Under the effect of the onshore wind and wave system, the barrier retreated and migrated eastwards into the barred lagoon system. Staggered dune advances resulted in an irregular encroachment of the barrier into the barred lagoon, and at one point dune advancement segmented the lagoon into a northern portion (Lake Preston), and a southern portion (Leschenault Inlet) The current coastal landforms of barrier dunes, lagoons and inlets reflect this history with the barrier dune system still slowly advancing landwards.

Cape Bouvard to Trigg Island

The Cape Bouvard to Trigg Island Sector of the Rottnest Shelf coast extends over 100 km in a north to 300° alignment. This sector is characterized by a complex nearshore bathymetry and extensive but discrete cells of Holocene sediment accretion. The southern boundary with the Leschenault-Preston boundary is defined by the abrupt termination of rocky shores south of Halls Head near Cape Bouvard. The northern boundary of the sector is defined by the emergence of a new and discrete, separate set of offshore ridges north of Trigg Island.

Bathymetry and Onshore Geomorphology (Fig. 8): The nearshore-onshore geomorphology and bathymetry is dominated by a series of north to 300°-trending (slightly oblique or parallel to shore) submarine to emergent aeolianite ridges, of the Spearwood Dune system. These are termed from west to east: the Five Fathom Bank Ridge, Garden Island Ridge and Spearwood Ridge. The ridges vary in prominence from a few metres to in excess of 60 m, and in continuity from continuous to discontinuous. Onshore the Spearwood Ridge forms the basis of the mainland shore and has developed topograhic barriers up to 60 m high between the inner Rottnest Shelf and the low Swan Coastal Plain further to landward. About 12 km offshore the Garden Island Ridge forms a perforate chain of rocky submarine reefs, pinnacles, and islands with interspersed passages. The Garden Island Ridge rises locally up to 65 m above the surrounding seafloor, and extends from near Cape Bouvard (where it is wholly submarine and discontinuous) to Rottnest Island where it abruptly terminates. The least prominent ridge, the Five Fathom Bank Ridge, is located a further 10 km to seaward where it forms a wholly submarine chain of rocky prominences rising up to 25 m above the surrounding seafloor. This ridge extends south past Cape Bouvard before terminating offshore from Myalup. Northward it merges with the Garden Island Ridge at Rottnest.

Discrete and significant bodies of Holocene sediment have developed across the submarine depression (20-25 m deep) only between the coastal mainland Spearwood Ridge and the offshore Garden Island Ridge, dividing it into a series of marine basins. In contrast, accretion in the depression between the Garden Island and Five Fathon Bank Ridges has been minimal. The Holocene sediment bodies consist of submarine to nearly emergent barrier and fringing sand banks that stand up to 30 m above the central axis of the depression. The bank structures may be capped by extensive terrains of low beachridges formed successively as the mainland shore prograded seaward across the adjacent submarine bank top to form cusps and tombolos. In addition, much of the seaward face of the mainland Spearwood Ridge is flanked by stabilised and mobile Holocene dunes.

The Swan River estuary also occurs within the sector but it is apparent that this fluvial influence has had little impact on the development of the coastal sector either geomorphologically or sedimentologically.

Stratigraphic Framework (Fig. 8): Holocene sediments of this sector overlie an irregular unconformity surface developed mainly on the Tamala Limestone; unconsolidated quartz sand (= Cooloongup Sand) occurs as sheets or wedges on low-lying parts of the unconformity surface. These quartz sands are relict, reworked from soils and other surficial materials during the post-glacial transgression (Passmore 1970), and are in part equivalent to the Eaton Sand of the Leschenault-Preston Sector. The Holocene sediments (up to 30 m thick) consist of shoaling and prograding sequences of quartzo-carbonate sand formed in submarine bank, beach, beachridge and dune environment (i.e. the Becher and Safety Bay formations). Sheets of carbonate muds up to 7 m thick have also developed in the quiescent marine basins formed between the major bank structures in the depression between the Spearwood and Garden Island ridges. Elsewhere in more exposed locations, Holocene carbonate sand veneers the submarine flanks of the mainland and Spearwood Ridges.

Sedimentation/erosion: Holocene sediment accretion in this sector has been largely controlled by (1) the interaction of the shelf wave regime, (2) the complex ridge-and-depression bathymentry, and (3) abundant sources of carbonate sediment. The Garden Island Ridge acts as a perforate barrier allowing a portion

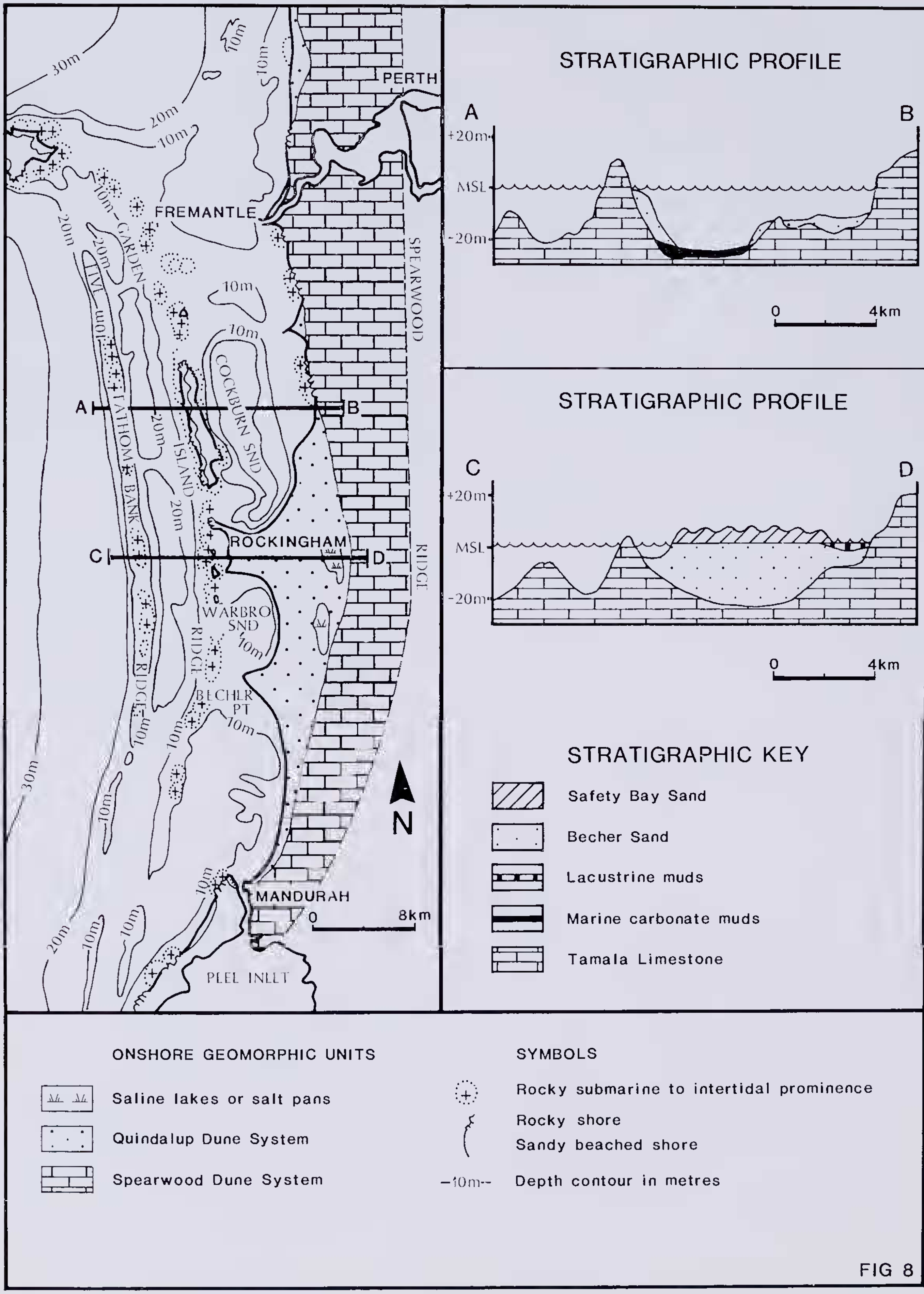

Figure 8.—Portion of coast of the Cape Bouvard-Trigg Island Sector showing: extensive Holocene cuspate and tombolo acretionary plains, general coastal form, geomorphic units, complex nearshore bathymetry of ridges and depressions, and selected stratigraphic profiles.

of the incident onshore waves through gaps and passages into adjacent parts of the otherwise sheltered, 20 to 25 m-deep depression to landward. Holocene sediment accretion has been largely restricted to these discrete loci of transmitted wave energy to form well defined submarine barrier and fringing bank structures.

Under the influence of prevailing swell and wind waves, sediment is transported northward along the exposed seaward faces of the Garden Island Ridge and mainland Spearwood Ridge. Where the offshore ridge shelters the shore along the Spearwood Ridge, transport is minimal and localised. Northerly storms impel a reverse transport on these exposed shores. The portion of the onshore waves passing through gaps in the Garden Island Ridge diverts sediment from the transport pathway on the seaward side. This sediment is then transported landward onto the adjacent submarine bank.

Refraction over the bank causes convergence of the wave that passes through the ridge crest toward the central axis of the bank. Sediment thus is impelled shoreward and contained within the bank locus. The convergence of wave energy as it passes shoreward also causes a concentration of littoral transport toward the central axis of the bank on the mainland shore. Progradation of the mainland shore seaward across the submarine bank top is centred on this convergence axis. The form of the prograding shore reflects the refractively-converged wave trains.

Since the end of the post-glacial transgression, sediment supply in this sector has come from two main sources: (1) erosion of the variably lithified Pleistocene aeolianite of the Garden Island Ridge which has supplied abundant carbonate lithoclast sand, and (2) production of skeletal material by the biota of seagrass meadows inhabiting the submarine banks in the system. This latter material is largely accumulated *in situ*. Transport into the system along the coast from the south has been a minor but locally important source of sediment.

In contrast to the carbonate dominate sediment of the bank systems, the mainland coast and adjacent shelf immediately to the north are blanketed by thin sheets of predominantly quartzose sands; this indicates there is no significant loss or supply of sediment to the system to the north.

Resultant Coastal Morphology: The Cape Bouvard-Trigg Island Sector coastal morphology has been extensively modified by both erosion and accretion since the end of the last post-glacial transgression and the coastal geomorphology reflects both these processes. Immediately following the transgression, the crest of the offshore Garden Island ridge was mostly emergent, forming a continuous elongate barrier island. Due to erosion on its seaward side, breaches have progressively developed and widened reducing the ridge crest to its present form. Accretion of sediment in submarine bank complexes in the depression to landward has been controlled by the breaching and subsequent erosion of the ridge crest. Formation of breaches and the activation of bank accretion in the adjacent part of the depression has been sequential rather than synchronous.

Each of the banks evolved in a well defined sequence. The initial stage of bank growth is the formation of a discrete submarine sediment lobe on the landward flank of the Garden Island Ridge adjacent to an initial breach. This lobe, supplied with eroded ridge material and locally generated skeletal sediment, progrades toward the mainland shore accompanied by continued erosional widening of the adjacent breach which in turn widens the evolving lobate bank. The lobate submarine structure eventually links with the mainland shore and sediment transported shoreward across the bank top then is supplied to the mainland shore where convergent littoral transport ensures it remains in the bank locus. This sediment supply initiates the progradation of the mainland shore seaward across the bank top, forming an extensive, low-lying beach ridge terrain. Ultimately the beach ridge terrain extends seaward, linking with emergent remnants of the Garden Island Ridge crest forming a tombolo. At present, the five major bank structures within the sector represent all stages of this evolutionary process from the submarine lobe to fully emergent stage.

Along more exposed portions of coast in this sector accretion has been restricted to development of thin carbonate and quartz sand sheets in the nearshore, and localised beach/beachridge/dune development on the seaward flanks of the emergent mainland and offshore Pleistocene limestone ridges. Elsewhere, locally, the coast is comprised of eroding, exposed Pleistocene limestone and, as a result, rocky shores with pocket beaches are developed.

Whitfords-Lancelin Sector

The Whitfords-Lancelin Sector extends 100 km in a 330° alignment. The southern limit of the sector is sharply defined by the recurrence of shore-parallel submarine rocky ridges, the Marmion Reef Ridge and the Staggie Reef Ridge, in the vicinity of Trigg Island, which then extend northward throughout the sector. However, the northern limit is gradational and defined by a transition from a wave dominated (this sector) to wind dominated (Wedge Island to Dongara Sector) pattern of Holocene sediment accretion. There is also a gradual change from relatively straight rocky shore (this sector) to deepy scalloped rocky shore.

This coast is characterised by a variety of features. The nearshore bathymetry has well defined, largely submarine, shore-parallel ridges. The coast consists largely of diffuse rocky coasts and pocket beaches interspersed with straight, beached coasts backed by the high dunes; locally, discrete and isolated cuspate dune-topped promontories extend up to 800 m seawards.

Bathymetry and Onshore Geomorphology (Fig. 9): A series of shore-parallel (330° trending) limestone ridges form the basis of the bathymetry and onshore geomorphology of this sector. There are four main limestone ridges. One forms the architecture of the shore and together with less prominent ridges immediately to the east this mainland ridge forms a topographic barrier between the low-lying Swan Coastal Plain and the coast. Lithified portions of the limestone ridge are exposed at the shore as diffuse rocky headlands and low (2-5 m high) seacliffs with intervening pocket beaches. Intertidal to submarine platforms and rocky prominences extend up to 150 m seawards of these rocky shores. The mainland limestone ridge may also be mantled by well vegetated, linear and parabolic dune forms. Immediately adjacent to the present coast, dunes on

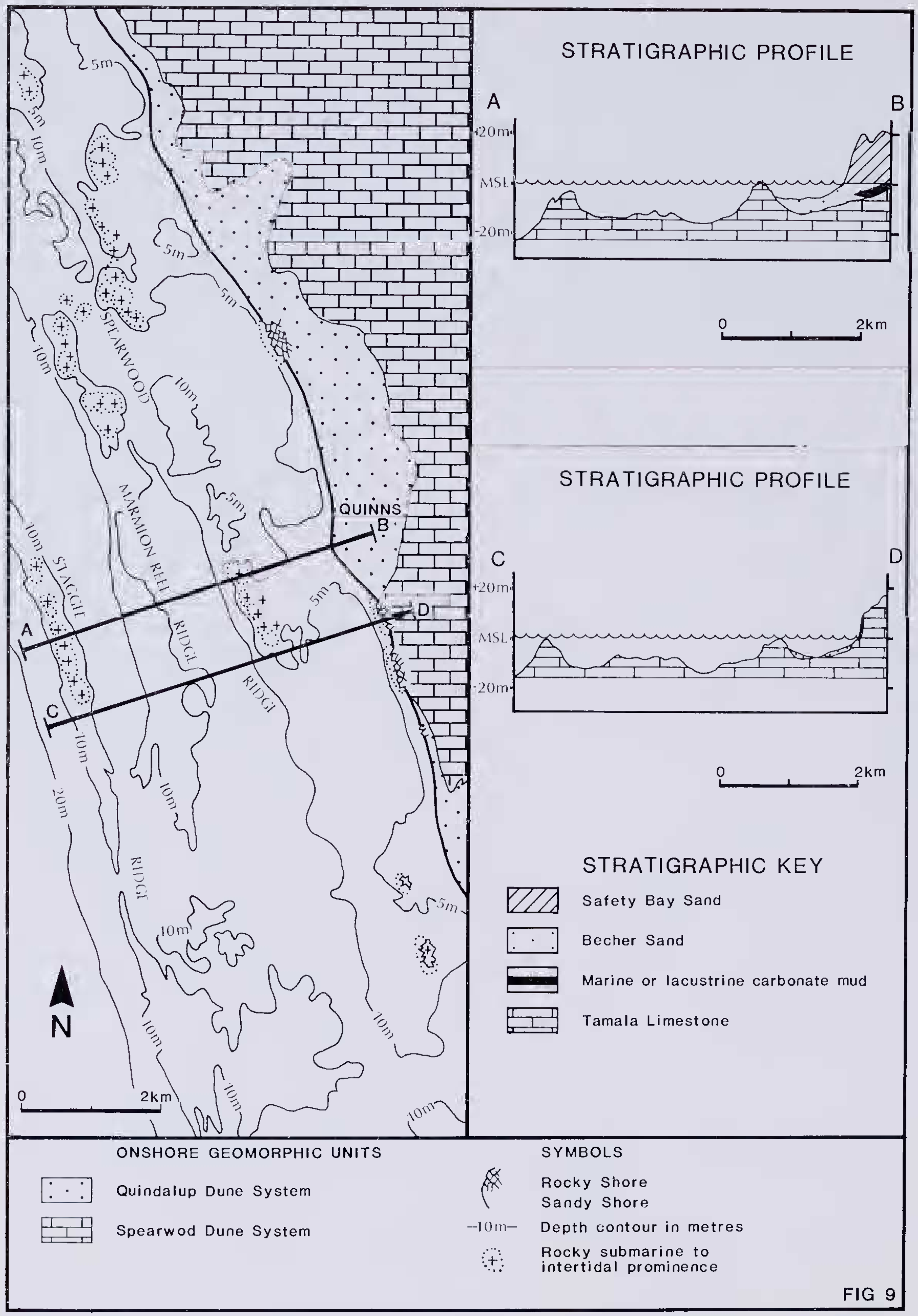

Figure 9.—Portion of coast of the Whitford-Lancelin Sector showing: small isolated Holocene accretionary cusps, general coastal form, geomorphic units, complex nearshore bathymety of ridges and depressions, and selected stratigraphic profiles.

the ridge flank tend to be linear and parallel to the shore. Inland dunes are either hummocky or parabolic. The parabolic forms are the stabilised remnants of large blowouts and they are uniformly oriented to the prevailing onshore westerly wind regime. Elsewhere, unconsolidated sands mantle the limestone ridge and form sandy beached coasts backed by high, well vegetated dunes. Locally these sandy coasts extend up to 800 m seawards to form discrete cusps. The cusps are also topped by well vegetated dunes. Adjacent to the beaches, parallel sets of beach ridges up to 5 m high are sometimes developed.

The other three limestone ridges, termed Staggie Reef Ridge, Marmion Reef Ridge and Spearwood Ridge are located ca 6, 4 and 2 km offshore. On these, the outer ridge, the Staggie Reef Ridge, is the least prominent, rising about 6 to 8 m above the surrounding seafloor to crest in a perforate chain of wholly submarine rocky prominences. The middle ridge (Marmion Reef Ridge) rises up to 15 m above the surrounding seafloor, and the most prominent parts of the ridge crest form small isolated rocky islets. The Spearwood Ridge appears as an extension of the mainland ridge of the Cape Bouvard-Trigg Island Sector; it occurs here as a discontinuance ridge of submarine prominences and emergent reefs close to shore. Water depths in the depressions between the ridges reach up to 15 m.

In several locations subridges extend obliquely across the trend of the three main ridges. These are oriented mainly between 0° and 010°, but several less prominent cross-trends are oriented at about 320°. The subridges form discontinuous chains of submarine rocky pinnacles and reefs commonly less prominent than the main ridges.

Locally there are small rivers that drain into the coastal areas but these are not significant either geomorphologically or sedimentologically.

Stratigraphic Framework (Fig. 9): Holocene sediment in the offshore and onshore areas varies greatly in distribution and thickness. Offshore, Holocene sands commonly form thin, discontinuous sheets which overlie low-lying portions of an irregular unconformity surface developed on the eroded remnants of the Tamala Limestone ridge-and-depression topography. Onshore Holocene dunes locally mantle the seaward flank of the mainland ridge. These dunes overlie either lithified Tamala Limestone or semi-lithified Pleistocene dune sands and soils. In the cuspate promontories the Holocene stratigraphic sequence is analogous to the beach/dune (Safety Bay Sand) and submarine bank (Becher Sand) overlying a Pleistocene unconformity as described for the cuspate and tombolo promontories of the Bouvard/Trigg Sector.

Sedimentation and Erosion: Holocene sediment accretion in this sector has been controlled by the interaction of 1) the prevailing onshore wave regime, 2) the nearshore bathymetry, and 3) the onshore wind regime. As in the Bouvard-Trigg Sector, accretion has occurred in loci of wave-energy convergence in the comparatively-sheltered, inter-ridge depression between the shoreline ridge and the adjacent offshore ridge. The accretionary sites, however, are not prominent and have prograded only relatively small distances to seaward. Sediment in these loci has again been derived from local benthic assemblages (principally the seagrass assemblage) and from the erosion of the Pleistocene ridges. Elsewhere along this sector Holocene accretion has only occurred as ENE to NE migrating dunes. These dune fields can extend up to several kilometres inland. The source of sediment for these dunes has probably been the underlying unconsolidated Pleistocene dune material supplemented at the coast by sediment leaked from the littoral transport regime.

Since the Pleistocene limestone ridge-and-depression topography first began to be inundated by rising post-glacial scalevels, it has been subjected to extensive but selective erosional modification. In general terms the less-lithifield aeolianite materials have been removed, leaving the more resistant portions as rocky submarine to emergent platforms, pinnacles and prominences, the processes and products of intertidal erosion of aeolianite limestone/sand (Semeniuk & Johnson 1985).

The erosional retreat of the shoreline however has not been uniform. As mentioned above, the interaction of the onshore wave regime and the nearshore bathymetry creates loci of wave convergence in the depression between the shore and adjacent offshore ridge. Where there has been both a pronounced convergence of wave energy (and hence convergence of littoral and sublittoral transport) and a supply of sediment, significant accretion has occurred. Where either of these factors has been less pronounced a locus of 'delayed' erosion has occurred. Although not accreting, the coast in this locus has not retreated at the same rate as the adjacent coast. Extensive landward migrating dune fields develop in these loci as a result of sediment supply due to diminished littoral transport. In some locations these landward migrating dunes have inundated marine marshes or lakes developed in depressions within the onshore topography. Clearly, the loci of arrested retreat and the loci of accretion are intergradational and, if sediment supply conditions were to change, accretion and progradation could begin in one, and erosional retreat in the other.

Resultant Coastal Morphology: Offshore marine erosion has left the more lithified remnants of the original ridge topography largely as submarine rocky prominences. Retreat of the shoreline has left rocky remnants as platforms and submarine pinnacles in a zone up to 150 m wide in front of the contemporary shoreline. Retreat of the shoreline has in places been accompanied by the ongoing landward migration of Holocene dunes.

The interaction between the prevailing onshore wave regime and the offshore bathymetry has created the longstanding loci of shelter between the shore and the adjacent offshore ridge. Where this effect has been particularly pronounced, the accretion of shoaling and prograding sequences of bank, beach, beachridge and dune sediments has developed isolated cusps. The cusps are analogous to those of the Bouvard-Trigg Sector but are smaller, due to the scale and separation of the Pleistocene ridges. Where the interaction of the wave regime and bathymetry has been less pronounced, erosional retreat of the coast has only been slowed and not wholly offset by accretion, resulting in cusp-shaped limestone residuals.

Wedge Island-Dongara Sector

The northermost sector of the Rottnest Shelf from Wedge Island to about Dongara extends 180 km in a 340° to north alignment. This coastal sector is characterised by a progressive, northwards change in the nearshore bathymetry and the configuration of the shoreline. The regular, shore-parallel submarine riges become increasingly dissected by oblique sub-ridge trends, before becoming largely discontinuous. Along the shore the cuspate promontories become less well defined and more asymmetric before disappearing altogether, and the limestone rocky shore becomes more deeply scalloped due to large-scale erosion. Northwards of Dongara the coast gradually changes in character from a complex nearshore system dominated by Pleistocene ridge-and-depression topography, to a higher cliffed coast developed in much older Phanerozoic rocks which are only locally blanketed by Quaternary coastal deposits.

Bathymetry and Onshore Geomorphology (Fig. 10): Offshore limestone ridges present in the Whitfords-Lancelin Sector extend into the Wedge Island-Dongara Sector but become progressively overprinted and dissected by oblique sub-ridges uniformly trending at about 010° to 015°. Coincident with this, the ridges become more discontinuous. The bathymetric prominence of the main ridges and sub-ridges vary from a few metres to over 12 m above the surrounding seafloor. Occasionally the ridge prominences form small rocky islets.

The coastal geomorphology consists largely of large erosional scallops into the Pleistocene limestone as well as discrete cuspate sediment promontories. The rocky coastline contains numerous small pocket beaches and it is interpersed with straight to gently arcuate beached coasts. Northwards the sediment cusps become asymmetric and eventually disappear north of Green Head. The dune terrains adjacent to the coast form a discontinuous and irregular coastal ridge. Mobile dunes and old vegetated dunes exhibit an alignment reflecting directions of blowouts or linear ridges between about 010° and 030°. Elongate, roughly shore-parallel lagoons or saline marshes may be developed in the coastal dune terrain. In places, these have been segmented and/or encroached on by dune migration.

Stratigraphic Framework (Fig. 10): Offshore the stratigraphy consists of discontinuous Holocene sand sheets overlyng an irregular unconformity surface developed on Tamala Limestone. Onshore modern mobile dune fields (Safety Bay Sand) overlie Pleistocene and older Holocene dune deposits. Locally in the cuspate promontories the Holocene stratigraphic sequences encountered are similar to that in the Whitfords-Lancelin sector with a well defined shoaling and prograding banks (Becher Sand) and beach, beachridge, dune sequences (Safety Bay Sand), as evidenced at Jurien Bay (Woods 1983).

Sedimentation and Erosion: Holocene sediment accretion has occurred in discrete coastal loci and in NNE migrating dune fields. The loci are the product of interaction between the wave regime and the nearshore bathymetry. Northwards in this sector the accretion of Holocene sediment in dune fields becomes increasingly more important, while the decline in the offshore ridge protection limits the occurrence of accretionary loci.

As in the Whitfords-Lancelin Sector, the erosion of the Pleistocene limestones has been pronounced but not uniform. In the southern parts of the sector the continuity and prominence of the offshore ridges result in variable erosional retreat of the mainland shore. In the north the offshore ridges are discontinuous and less prominent, consequently retreat of the adjacent shore has been more irregular.

Resultant Coastal Morphology: The coastal morphology of this sector reflects the decline in shelter afforded by the offshore bathymetry and the increase in onshore development of NNE migrating dunes. Towards the north some of the erosional scallops and accretionary cuspate promontories become asymmetric. Some of the cusps are erosional and the asymmetry reflects active migration of dunes NNE and the effects of an eroding coast with a pronounced NNE trend of relict Pleistocene and Holocene dune forms. The accretionary cusps (like Jurien Bay) tend to be largely symmetric despite periods of differential accretion on the NW and SW shores. In the northern parts of the sector the coast is devoid of prominent cusps which reflects the lack of offshore bathymetric features for protection.

Discussion of significance of results

There are several significant aspects of the classification of coastal sectors presented above. Firstly, it is obvious that the various coastal sectors can be separated in terms of morphology, dynamics, history and function. Secondly, comparisons should only be made between relevant portions of similar coastlines: for instance, the data, erosion rates, coastal dynamics and conclusions of Semeniuk & Meagher (1981) and Semeniuk & Searle (1985c) are not comparable with, and are irrelevant to, sections of the coast at (say) Becher Point or Quinns Beach. On the other hand, similar parts of the coast within or between sectors can be more confidently compared. For instance, the data on the evolution of individual cusps or sandy promontories as described by Woods & Searle (1983), Searle (1984) and Searle & Woods (1984) at Warnbro Sound are applicable to sedimentation sites such as Whitfords Point and Jurien. The sector approach thus allows realistic comparisons and use of coastal dynamic models between similar portions of coastline, but also allows comparison between the similar components of differing sectors of coast because a given section of coast is then viewed in regional perspective. These first two points have important implications for coastal management.

The third aspect is that the categorisation of the coast into sectors provides a regional to subcontinental framework wherein the origin and maintenance of the coast in a geological time scale can be more readily understood.

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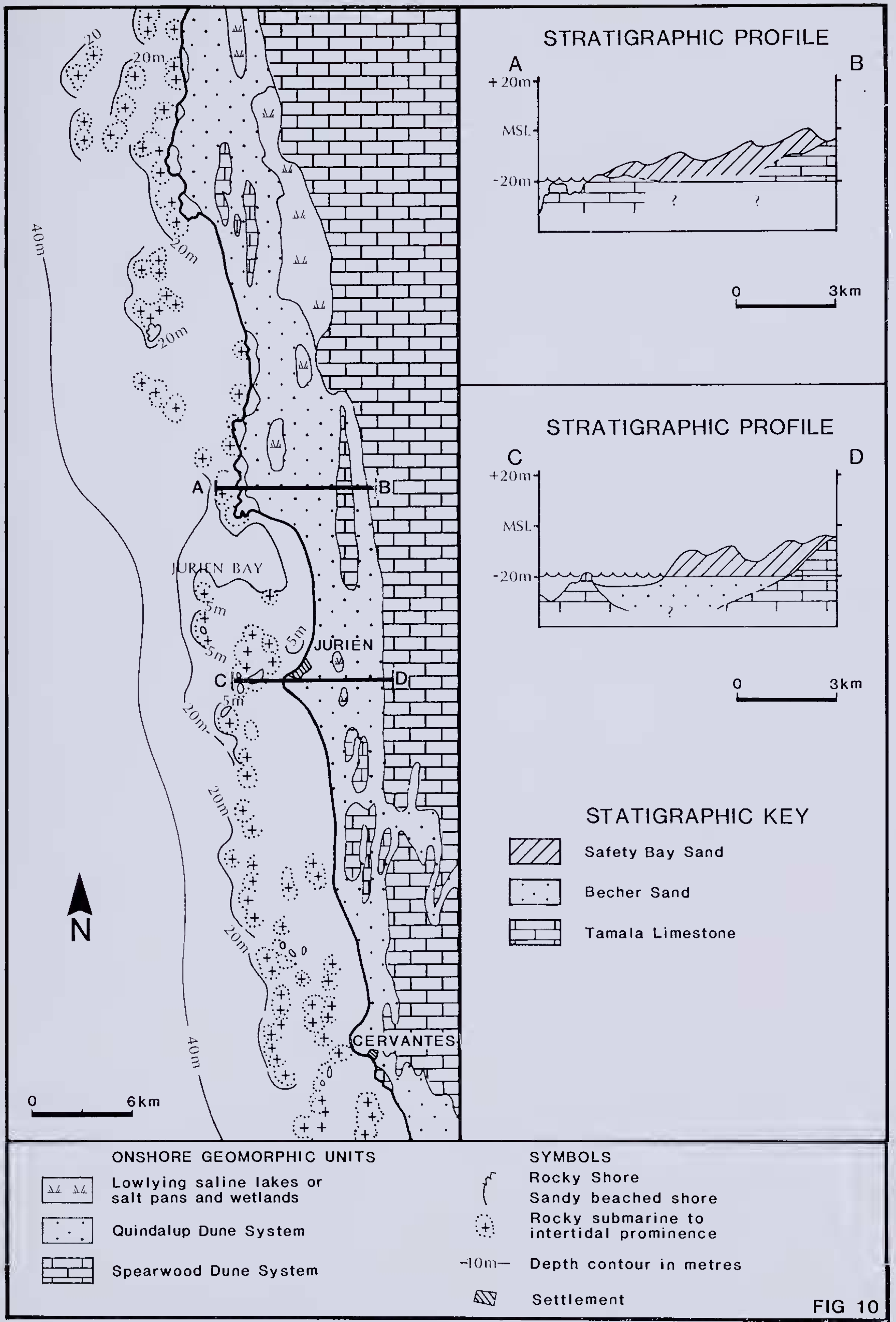

Figure 10.—Portion of coast of Wedge Island-Dongara Sector showing: small isolated Holocene accretionary cusps, large-scale erosionally-scalloped coastal form, geomorphic units, complex nearshore bathymetry of ridges and depressions, and selected stratigraphic profiles. Map modified after Lowry (1974), with information supplemented by the authors.

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